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# Use of abaca and banana fibers for water purification

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## ABSTRACT

Some previous researches show the potential of natural fibers for the production of filters, as these materials are commonly used in the production of tea bags or filters for tobacco. This paper focuses on the use of banana and abaca fiber for water purification, showing thus their capacity for heavy metals adsorption; on the other hand, since the filtering media used is formed by natural materials, microbiological analysis was carried out, ensuring that no organic pollution happens during the filtering process. This research has been approached with cupper and iron ($Cu^{2+}$ and $Fe^{2+}$), being both materials commonly used in water supply systems. Spanish regulation allows maximum levels of 2 mg/L for $Cu^{2+}$ and 0.2 mg/L for $Fe^{2+}$. Two types of vegetable fibers were used: banana fiber from Canary Islands and abaca fiber from Ecuador. Also different length fibers have been used, studying that way the effect of the superficial area on the adsorptive of ions on natural material. The amount of fiber used has also been varied, from 5 to 20 g per 100mL of water sample.
Concentration of the metallic ions has also been modified, i.e.: 2, 4 and 6 mg/L for $Cu^{2+}$ and 0.2, 0.4 and 0.6 mg/L for $Fe^{2+}$. Ions were either studied separately or when both were present in concentrations mentioned above. It has been shown that both types of fiber show ability for metallic content reduction in water, without introducing microbial pollution in treated samples.

**Keywords:** *abaca fibers, banana fibers, water purification, $Cu^{2+}$, $Fe^{2+}$.*

## 1. INTRODUCTION

Nowadays water found in nature cannot be commonly used directly for human consumption, because it is not chemically and biologically pure enough. There are a wide variety of water purification processes, as distillation, evaporation, decantation or filtration; the procedure selected depends mainly on the degree of pollution. This paper uses the filtration process, which is a physico-mechanical procedure for the separation of substances in different phases, employing a porous medium (named filter). Filters can be opened to the atmosphere (gravity filters, which are the ones used during this research) or placed in a tank (pressure filters).

Elements involved in a filtration process are: filtering media, the fluid containing the substance to remove, pressure difference, which makes the fluid passing through the filtering media and a mechanical device (the filter itself) which supports the filtering media and contains the liquid, allowing thus the process [1].

Usual components of filters are polyamide, which supports the rest of filtering elements, sand and active carbon. Sand filters emulate natural filtering process, removing bacteria and small particles [1]. Active carbon is one of the most used materials, because of its good adsorption properties; it can be usually found as powder, granules, fibers, tissues or discs, being the most recently used in specific applications. Powder usually has a particle size between 15 – 25 µm and is used when the solute shows diffusion problems; granulate active carbon has a size around 1000 – 5000 µm and is mainly used in fixed bed devices for continuous adsorption process.

Increased awareness about environment and pollution makes processes and products to evolve towards a "greener" economy, with higher efficiency, coming from renewable sources, with lower GHG's emission and using recyclable materials. Natural fibers appear in the industrial scenario as a possibility for substituting some synthetic materials; it has been reported that the production of abaca fibers needs 60% less energy than glass fibers [2]. Furthermore, natural fibers have neutral $CO_2$ emissions and are 100% biodegradable.

This paper shows the results obtained for purification of waters polluted with different concentrations of ions $Cu^{2+}$ and $Fe^{2+}$ (2, 4 and 6 mg/L for $Cu^{2+}$ and 0.2, 0.4 and 0.6 mg/L for $Fe^{2+}$, as well as combination of both ions, in order to determine if the presence of different ions affects the adsorption of the first one). European Directive 15/11/CE establishes the maximum concentration for these ions of 2.0mg/L for $Cu^{2+}$ and 200µg/L for $Fe^{2+}$, with the aim of guaranteeing an adequate supply of water accomplishing with quality standards, preventing and reducing the pollution of waters.

Different researchers have found that natural materials are potentially suitable to be used for water decontamination. Wheat bran was found to be useful for cadmium removal[3], while hemp fiber has been used for $Cd^{2+}$, $Pb^{2+}$ and $Zn^{2+}$ [4]. Wastes from yucca production have been also investigated for $Cd^{2+}$ and $Zn^{2+}$ removing from water solutions [5]. Different ions can be also removed by the use of rice hulls [6], jute fiber [7], coconut shells [7, 8], peanut shells [9], corn cobs [10], among some other natural materials [11 -14].

Heavy metals can be successfully determined by different technical means, as atomic absorption or colorimetric techniques. Atomic absorption without flame (in graphite camera) usually offers the lowest detection limits among different methods, being shortly influenced by the analytic complexity of the sample to analyse. This method offers good results for natural and potable water with moderate levels of different ions. This is the reason for using this equipment in the analysis of the samples processed in this research.

## 2. EXPERIMENTAL SECTION

### 2.1. Materials.

Abaca fiber was kindly supplied by the company Celesa (abaca fibers from Ecuador), while banana fibers were extracted at Universidad de Las Palmas de Gran Canaria. Fibers were cut to 5 cm, 2.5 cm and 0.5 cm length, and also grinded to get a fluffy material.

Active carbon was used in powder, from PANREAC (121237-1609), with maximum contents in copper of 0.005%, 0.05% of iron, 0.005% of nickel and 0.005% in plumb. Filters also were prepared with a layer of washed sea sand (fine grained, QP), with average grain size under 0.30 mm, also from PANREAC (211161-1210). Polyamide fiber (perlon) was used as support media for all components inside the filter.

Water to be purified has been prepared with running water contaminated with $Cu^{2+}$ and $Fe^{2+}$ patrons of 1000ppm, from PANREAC, preparing solutions of 2, 4 and 6 mg/L for $Cu^{2+}$and 0.2, 0.4 and 0.6 mg/L for $Fe^{2+}$, 6 mg/L $Cu^{2+}$and 0.6 mg/L $Fe^{2+}$, 4 mg/L $Cu^{2+}$ and 0.4 mg/L $Fe^{2+}$ and 2 mg/L $Cu^{2+}$ and 0.2 mg/L $Fe^{2+}$, for the study of influence of the presence of different metals to the one to be analysed. Water was analysed before its pollution, in order to establish their parameters.

### 2.2. Manufacturing of filters.

Different types of filters were produced, in order to determine the behaviour of all components for $Cu^{2+}$ and $Fe^{2+}$ adsorption. Table 1 contains different typologies of filters produced. It is important to note that each typology of filter has been used under nine different solutions (three concentrations of $Cu^{2+}$, and respectively of $Fe^{2+}$ and three solutions combining both ions), and, in order to get more accurate results, at least five replicas of the filter were produced.

Figure 1 shows a picture of a filter containing 2.5 cm length abaca fiber (typology 7) and another one with grinded abaca fiber (typology 15).

**Table 1**. Different filters configurations prepared for water filtration

| Filter | Layer 1 | | Layer 2 | | Layer 3 | | Layer 4 | |
|---|---|---|---|---|---|---|---|---|
| | Material | Amount (g) | Material | Amount (g) | Material | Amount (g) | Material | Amount (g) |
| 1 | Polyamide | 5 | | | | | | |
| 2 | Polyamide | 5 | Active carbon | 5 | | | | |
| 3 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | | |
| 4 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 5 cm abaca fiber | 4 |
| 5 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 5 cm abaca fiber | 8 |
| 6 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 5 cm abaca fiber | 12 |
| 7 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 2.5 cm abaca fiber | 4 |
| 8 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 2.5 cm abaca fiber | 8 |
| 9 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 2.5 cm abaca fiber | 12 |
| 10 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 0.5 cm abaca fiber | 4 |
| 11 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 0.5 cm abaca fiber | 8 |
| 12 | Polyamide | 5 | Active carbon | 5 | Sand | 50 | 0.5 cm abaca fiber | 12 |
| 13 | Grinded abaca fiber | 5 | | | | | | |
| 14 | Grinded abaca fiber | 10 | | | | | | |
| 15 | Grinded abaca fiber | 20 | | | | | | |
| 16 | Grinded banana fiber | 20 | | | | | | |

**Figure 1**. Left, filter with polyamide, active carbon, sand and abaca fiber (bottom to top); right, filter with grinded abaca fiber.

**2.3. Production of samples.** Samples were prepared by filtering 100 mL of the solution and collecting the filtered liquid. To accurate an adequate conservation of samples after filtration (for metals determination) 100 µL of $HNO_3$ 1N were added per 50 mL of sample. Samples for microbiological analyses must be prepared and analysed, as is not possible to preserve them to avoid errors.

**2.4. Samples analysis.** Samples were analysed in a graphite camera atomic absorption spectroscope VARIAN (AA-240Z with

Graphite chamber). The prepared solutions were also measured to precisely define their metals concentration previously to the filtration process. Microbiological behaviour of filters was determined by the use of sterilefiltering membranes (pores of 0.45 µm), from PALL corporation, which underwent a cultivation process in ovens for 24 hours at 35 ± 2 ºC, for determination of total coliforms (m-Endo method).

## 3. RESULTS SECTION

It has been proved that polyamide does not modify the concentration of ions in water solution, as the average efficiency obtained is 1.4 %; this fact can ensure this material just acts as support of the remaining layers of materials which form the filter. Active carbon filters (typology 2) show an important reduction of 33.9 % of $Cu^{2+}$ (initial concentration of 6 mg/L).

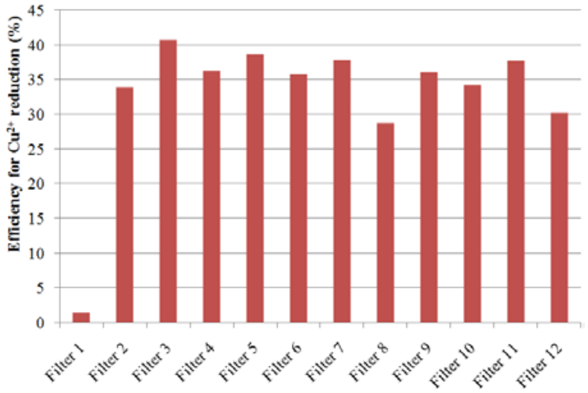


**Figure 2**. Average efficiencies (in %) of filters for $Cu^{2+}$ reduction (initial concentration of 6 mg/L).

Filters including also a layer of sand show an average reduction of $Cu^{2+}$ ions of 40.8 %, which is slightly higher than efficiency obtained just for granular active carbon.

Figure 2 shows average values for reduction of $Cu^{2+}$ ions in a 6 mg/L solution; it is clearly observed that there are no significant differences among all different typologies of filters (except for typology 1, which just consists on polyamide), as stated after a simple Anova statistical analysis, showing p – value > 0.05, and an average value of 35.5 % of cupper reduction.

So, it can be concluded that the use of long abaca fibers (0.5 cm, 2.5 cm and 5 cm) does not improve the reduction of copper ions; as one important aspectin adsorption is the surface area of the material, grinded fiber is expected to reach higher levels of ions reduction. Table 2 show the efficiency of filters with grinded fiber; it is observed that filters with higher amounts of fiber show higher reduction of $Cu^{2+}$, with similar levels of reduction for $Fe^{2+}$. This fact may mean that abaca fiber has higher affinity to copper ions; on the other hand, if these results are compared with the ones obtained for banana filter (typology 16), it seems that banana fiber shows more affinity to $Fe^{2+}$.

**Table 2**. Efficiency (%) of different filters with grinded abaca and banana fiber for different solutions

| Filter | | Initial concentration of $Cu^{2+}$ | | | Initial concentration of $Fe^{2+}$ | | |
|---|---|---|---|---|---|---|---|
| | | 6 mg/L | 4 mg/L | 2 mg/L | 0.6mg/L | 0.4mg/L | 0.2mg/L |
| Grinded abaca fiber | 13 | 13.4 | 33.1 | 60.2 | 39.6 | 45.0 | 53.8 |
| | 14 | 23.6 | 29.6 | 74.1 | 48.6 | 44.0 | 67.0 |
| | 15 | 71.8 | 49.3 | 75.4 | 45.3 | 39.3 | 60.4 |
| Grinded banana fiber | 16 | 30.3 | 28.1 | 30.5 | 65.0 | 70.4 | 67.8 |

It is important to note that these filters just consist on grinded abaca or banana fibers, without any other component, and that efficiencies reach up to almost 72 % for abaca fiber and 30 % for banana fiber, which are similar values to those obtained by active carbon. As comparison, tea residues are reported to show an efficiency of 41-46 % for $Cu^{2+}$ [14, 15], while rice husk efficiency for these ions is found to be around 45 % [16]; jute fiber can remove up to 34.9 % of $Cu^{2+}$ [7]. In Table 3 it could be seen the efficiency of filters with grinded fiber, when both metals are present in the solution. It is observed that $Cu^{2+}$ reduction is improved when $Fe^{2+}$ is also present for abaca filters, however it is not modified for banana filter. Nevertheless, efficiency in $Fe^{2+}$removing is not as clearly affected by the presence of $Cu^{2+}$ions, tending to be reduced for both types of fibers filters. Water filtered through abaca or banana fibers have shown no growth of bacteria in the membranes, meaning that these types of fibers are safe for water purification. This can be observed in figure 3, where no bacterial colony growth has taken place.

**Table 3**. Efficiency (%) of filters with grinded fiber for combination of metals

| Filter | | Efficiency of $Cu^{2+}$ reduction | | | Efficiency of $Fe^{2+}$ reduction | | |
|---|---|---|---|---|---|---|---|
| | | 6 mg/L of $Cu^{2+}$ and 0.6 mg/L of $Fe^{2+}$ | 4 mg/L of $Cu^{2+}$and 0.4 mg/L of $Fe^{2+}$ | 2 mg/L of $Cu^{2+}$and 0.2 mg/L of $Fe^{2+}$ | 6 mg/L of $Cu^{2+}$ and 0.6 mg/L of $Fe^{2+}$ | 4 mg/L of $Cu^{2+}$and 0.4 mg/L of $Fe^{2+}$ | 2 mg/L of $Cu^{2+}$and 0.2 mg/L of $Fe^{2+}$ |
| Grinded abaca fiber | 13 | 49.8 | 51.1 | 61.1 | 38.0 | 40.7 | 32.2 |
| | 14 | 57.2 | 72.6 | 11.3 | 40.5 | 38.4 | 28.5 |
| | 15 | 74.6 | 59.9 | 8.1 | 40.9 | 30.9 | 32.0 |
| Grinded banana fiber | 16 | 31.2 | 26.6 | 30.5 | 69.5 | 62.7 | 58.7 |

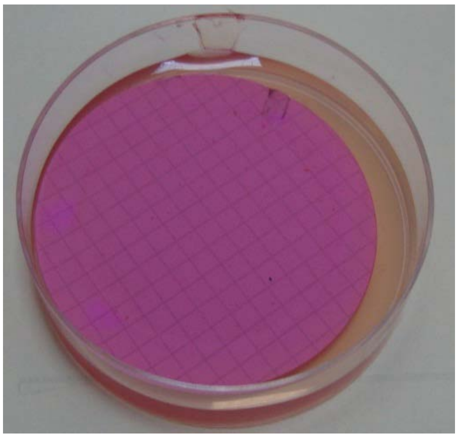

**Figure 3**. Membrane filter after cultivation, showing no bacterial growing

## 4. CONCLUSIONS

Banana and abaca fibers are both suitable to be used for water purification, as they show acceptable efficiencies in $Cu^{2+}$ and $Fe^{2+}$ removing. Abaca fiber shows higher affinity to $Cu^{2+}$, while banana fiber is higher to $Fe^{2+}$. The increased content in fiber and a lower size of fiber are correlated with a higher reduction in $Cu^{2+}$. The efficiency of $Cu^{2+}$ reduction is increased when $Fe^{2+}$ ions are present in the solution, while $Fe^{2+}$ adsorption decreases when the solution also contents $Cu^{2+}$. Higher efficiencies for the reduction of $Cu^{2+}$ and $Fe^{2+}$ could be achieved by the combination of both types of fibers. Since the microbial growth was absent the use of banana and abaca fibers is safe for water purification.

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